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ABSTRACT

The supply of scientists and engineers should be viewed not only in terms of quantity, but also in terms of quality and preparation. Forecasts have proven inaccurate in the past so that industry must assure an adequate quantity of students entering the science and engineering fields by the promise of employment. The quality of the professionals can be assured by attracting the best of the foreign students as well as the best American students. And good preparation can be assured by keeping the relationship between the industry and the educational community dynamic. Further, it is necessary for the universities to join in seeking additional innovative ways to make academic and industrial scientists and engineers more aware of each other's jobs and challenges through greater cooperative efforts. (JMF)

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Dr. Arthur M. Bueche, Vice President - Research and Development, General Electric Company

THE SUPPLY OF SCIENTISTS AND ENGINEERS

Presented at:

The 150th
Anniversary Convocation
Rensselaer Polytechnic
Institute

October 11, 1974

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Dr. Arthur M. Bueche
Vice President - Research and Development
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THE SUPPLY OF SCIENTISTS AND ENGINEERS

I'd like to think that my participation on this auspicious occasion is a reflection of the excellent cooperation over the years between Rensselaer Polytechnic Institute and General Electric, and especially GE's Research and Development Center. This close working relationship was epitomized during the past year by the award of a Nobel Prize to one of our mutual associates and friends, Ivar Giaever. Ivar was taking courses at RPI at the time he did his Nobel Prize-winning work at GE. (By the way, it's rumored that after Ivar got started on that work, one of his colleagues at the R&D Center asked him: "Ivar, are you sure all this fiddling with superconductive tunneling won't interfere with your education?")

Well, we don't insist, or even expect, that every one of our joint efforts must result in a Nobel Prize. But I do think there are some things industry and universities can tell each other. I'm looking forward to such a dialogue on today's topic: the supply of scientists and engineers.

From my point of view, previous discussions of the supply of scientific and technical people have overemphasized numbers. This excessive attention to quantity introduces two dangers.

Surplus and Shortage

First, it leads to wide swings in support of, and interest in, engineering. Frankly, our manpower data and forecasting techniques just aren't good enough to support many of the generalizations that have been based on them. The historic roller coaster of real or apparent surplus, followed by shortage, is in part a result of short-term swings in support. It also reflects the way students perceive their future job opportunities, superimposed on an educational pipeline four to eight years long. Engineers might define this situation as an undamped system with positive feedback, not helped at all by the surprising lack of reliable manpower data.

Second, engineers and scientists aren't standardized products that can be categorized like steel ingots or tons of coal. The quality and preparation of each individual the universities produce is just as important as — really more important than — the total number of science and engineering graduates turned out. Furthermore, in the long run, the quality of these individuals could influence the demand for engineers and scientists. Certainly, no business or social system can afford to support relatively inadequate or inefficient technical workers. Organizations can turn to other alternatives, such as the importation of technology, or they can change their strategies so as to compete on the basis of other strengths.

For this reason, I'd like to discuss my subject under three headings: not only quantity, but also quality and preparation. To put it another way: those of us in industry are going to need large numbers of people from the universities in the years ahead. But, more importantly, we're going to

need very good people, and we're going to need people prepared with a realistic picture of the problems and opportunities they will confront.

Assuring Quantity

On the subject of forecasting the quantity of scientists and engineers, Figure 1 tells a story of past failures. Those beautiful future projections of the total U.S. employment of engineers — the straight lines — were made by the Bureau of Labor Statistics just prior to the two periods indicated. What really happened is marked "actual." Indeed, the situation is even worse than it appears here, because the number of "actual engineers" is the number of people who reported to the Bureau of Census and other surveys that they *believed* themselves to be employed as engineers.

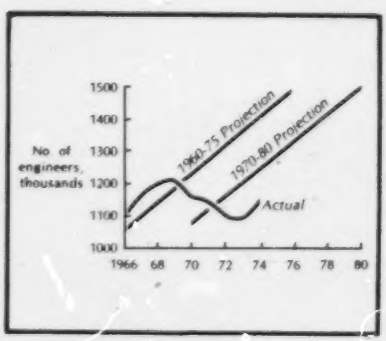

Figure 1

John Alden of the Engineering Manpower Commission estimates that at least 40 percent of these people are not engineers by professional society criteria. On the other hand, he also estimates that 45 percent of the people holding engineering degrees are not working as engineers.

So, many of the figures we have available are, at best, somewhat nebulous. However, we do have some slightly harder numbers. This year, it seems safe to assume that about 64,000 B.S., M.S., and Ph.D. degrees in engineering will be awarded. Figure 2 shows the number of such degrees awarded each year back to 1920. The postwar impact is evident enough, but surprisingly the post-Sputnik buildup is not as apparent as one might expect. And it will come as no surprise to many in academia today that the 1974 totals are below those of a couple of years ago.

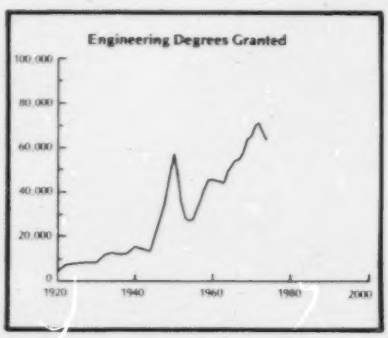

Figure 2

How about the future? Well, the previously illustrated problems with the Bureau of Labor Statistics projections point to the dangers of trying to make extrapolations. The recent history of studies sponsored by leading technical societies has been equally disastrous.

So, I could be conservative and estimate that U.S. engineering schools will be producing 60,000 graduates per year in 1980, without much change by the year 2000 (Figure 3). Or, I could estimate 75,000 in 1980 and 90,000 in 2000 (Figure 4). Or maybe you'd prefer a middle-of-the-road projection (Figure 5). The point is that we have insufficient data for making really reliable estimates. And, of course, demand will have a great deal to do with the eventual supply.

One thing that might make the top line more likely is international competition, especially between the United States and the Soviet Union. The most reliable annual figures on engineering graduates in the U.S.S.R. are from 1961 through 1965, but you can see in Figure 6 that during that period their "diplom" graduates outnumbered our total graduates by more than two-to-one. There is some difficulty in comparing figures for the two nations because of different definitions. In this regard, it might be noted that just last month a new U.S. - U.S.S.R. agreement for standardizing and exchanging this kind of information was signed. In any event, these numbers should help dispel any complacency we may feel about U.S. leadership in engineering.

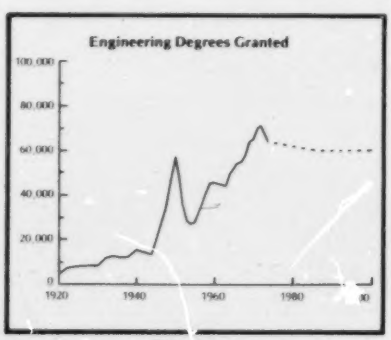

Figure 3

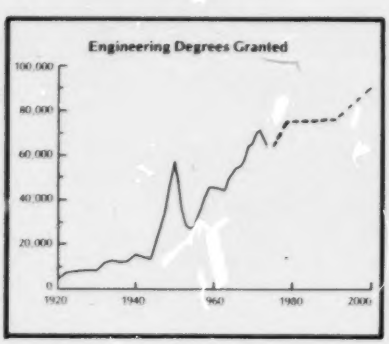

Figure 4

In discussing the U.S. potential for engineering graduates, it might appear that there is a "ceiling" on the number of young Americans who have both the desire and the ability to

become scientists and engineers. During the 1960s — the period from Sputnik to Apollo — some believe that we reached that ceiling. During that period, about 3.6 percent of U.S. 18-year-olds went on to receive bachelor's degrees in science and engineering. As the glamor of space diminished after 1970, this percentage fell off.

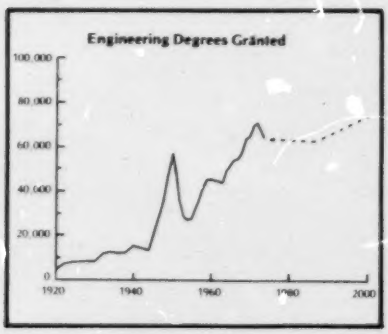

Figure 5

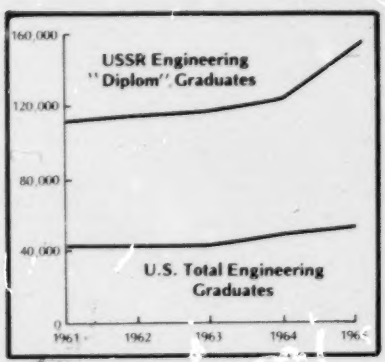

Figure 6

But does this mean that 3.6 percent is the highest we can expect to achieve under the most favorable circumstances? Not necessarily. There's a catch to that number. You see, that "3.6 percent of U.S. 18-year-olds" really means that about 6.1 percent of 18-year-old *men*, but only 1.1 percent of 18-year-old *women*, went on to get degrees in science and engineering. And the figures for minority-group 18-year-olds are even lower than those for women — less than 1 percent.

Obviously, women and minority groups represent a substantial source of potential technical talent that this nation has not been using to its best advantage. This situation certainly should, and will, change.

Assuring Quality

Now, let's turn to the matter of quality of the product. At our R&D Center, we try to keep an eye on the quality of the scientists and engineers turned out each year by the universities, especially the Ph.D.s. Fortunately, so far we've seen nothing to indicate any decline. However, I can see a couple of possible concerns regarding the future capability of this nation's technical and scientific talent.

One of these concerns is the changing role of foreign countries in providing a substantial share of the top-quality students in U.S. engineering schools. Specifically, it has been estimated that fully one-third of the engineering doctorates awarded by U.S. universities in recent years have gone to foreign nationals. In the past, many of these highly talented and well-trained Ph.D.s remained in this country. Now we are beginning to see a downturn in enrollment of foreign nationals in graduate programs, and this, coupled with immigration restrictions, will certainly lead to a reduction in the total number of Ph.D.s available to the U.S. economy.

A second potential problem involves the question of whether students of top quality are choosing science and engineering careers. Right now, we just don't have the data to answer this question. However, the British do collect such data. Their most recent findings indicate a decline in the proportion of top students going into science and engineering, with a corresponding increase in the proportion of top students entering other fields, such as medicine and the law. This is a reversal of a long-time trend in England that saw technical fields as the first choice of the most qualified students. Is this change occurring in the United States as well? We just don't know. We should find out. Data collection for manpower forecasting should seek information on the quality as well as the quantity of students.

Assuring Good Preparation

Even if an adequate supply of high-quality entering students is assured, we in industry still aren't assured of having the talent that we will need. Future scientists and engineers must also be prepared with a realistic idea of the nature of the work and of the opportunities open to them. This area is the one in which I see the greatest potential problems. For one thing, it's a matter of unfulfilled expectations. When, after four years — or eight — of intensive study and self-image building, often at great personal sacrifice, a graduate can't find a position that will allow him to do the job he's been dreaming about, his morale and self-confidence are severely impaired. This leads to loss of vitality and creativity, and, in some cases, to leaving the profession in which he has invested so much.

A few years ago, Dean Frederick Terman of Stanford said:

> The typical holder of a new Ph.D. in science, and, to some extent, in engineering as well has been trained for a career that emphasizes research, particularly basic

research conducted in an academic environment. That is, faculty members have tended to produce Ph.D.s in their own image, with only a minimum of thought as to the needs of the industrial sector of the job market. Yet it is the industrial sector that must be depended upon to provide employment for the bulk of the new Ph.D.s in the decade ahead.

Both academic and industrial leaders have been aware of this problem for a long time. But it has remained one of those areas where a lot more gets said than gets done.

Changing Relationships

It should be apparent that past relationships among the three major forces in graduate education -- universities, industry, and government -- will be changing and adjusting as the years go by. The decline in Federally funded fellowships from 51,000 in 1968 to 6,600 in 1974 is a rather dramatic example. And, on demographic considerations alone, it's obvious that there will be fewer academic openings than in the past.

There have been some positive steps to break down the barriers between the sectors that employ Ph.D.s. Some of our best scientists and engineers are serving as adjunct professors right here at RPI and elsewhere, thereby (hopefully) bringing to the students some new perspectives. Our joint program with the University of Rochester on laser-ignited fusion is just one example of industrial-academic-governmental collaborative effort. As another "for instance," General Electric and other companies are presently participating in a manpower-exchange program with the Federal government. And there are many more.

Improving Interchange

But I'd like to encourage the universities to join in seeking additional innovative ways to make academic and industrial scientists and engineers more aware of each other's jobs and challenges. As I understand it, faculty members are now reluctant to spend a year in industry, because they would earn no credit toward academic advancement. Yet, a year in industry certainly makes a faculty member much more aware of the real-world impact of both his research and his teaching. This just has to make him a better researcher and a better teacher. I hope the universities can find a way of recognizing this.

There's another potential problem in the preparation of scientists and engineers that I'd also like to talk about. This is the proliferation of "technology degrees" at the four-year level. This practice has grown to the point where one technology degree is now granted for every five engineering degrees.

To me, the technology degree indicates an education with high skill content, but with less emphasis on fundamentals than the traditional B.S. People with such preparation can be highly useful to industry in such areas as manufacturing, installation and servicing, and plant layout. But it remains to be seen how much they can contribute to solving the truly limiting problems of the next few decades -- particularly in research and development.

It seems to me that it would be unwise to go overboard on bachelor of technology programs before industry gets a chance to see in which areas these people can perform best. Particularly, please don't weaken the traditionally strong B.S., M.S., and Ph.D. programs, the products of which we will need more than ever.

Four Recommendations

Let me conclude, then, by summing up my recommendations regarding the future supply of scientists and engineers:

1) An important short-run need is for better data that will enable us to project supply adequately. And we will need data on quality as well as quantity.

2) Women and minority groups represent a large pool of potential scientists and engineers, and I am confident that the nation will make far better use of these talents than it has in the past.

3) Universities should not go too fast on producing "technology degree" holders. The vast problems of the 1970s and 1980s -- in energy, materials, and other areas -- will require large numbers of creative people with strong backgrounds in fundamentals.

4) We must recognize that the greatest opportunities for using tomorrow's technical talent will be in industry. Having recognized this, we must be more innovative and receptive to new ideas for promoting the interchange of ideas and people among industry, universities, and government.

Let me conclude by saying as a representative of industry: I assure you we will try to offer challenging employment to the best products of your universities.

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